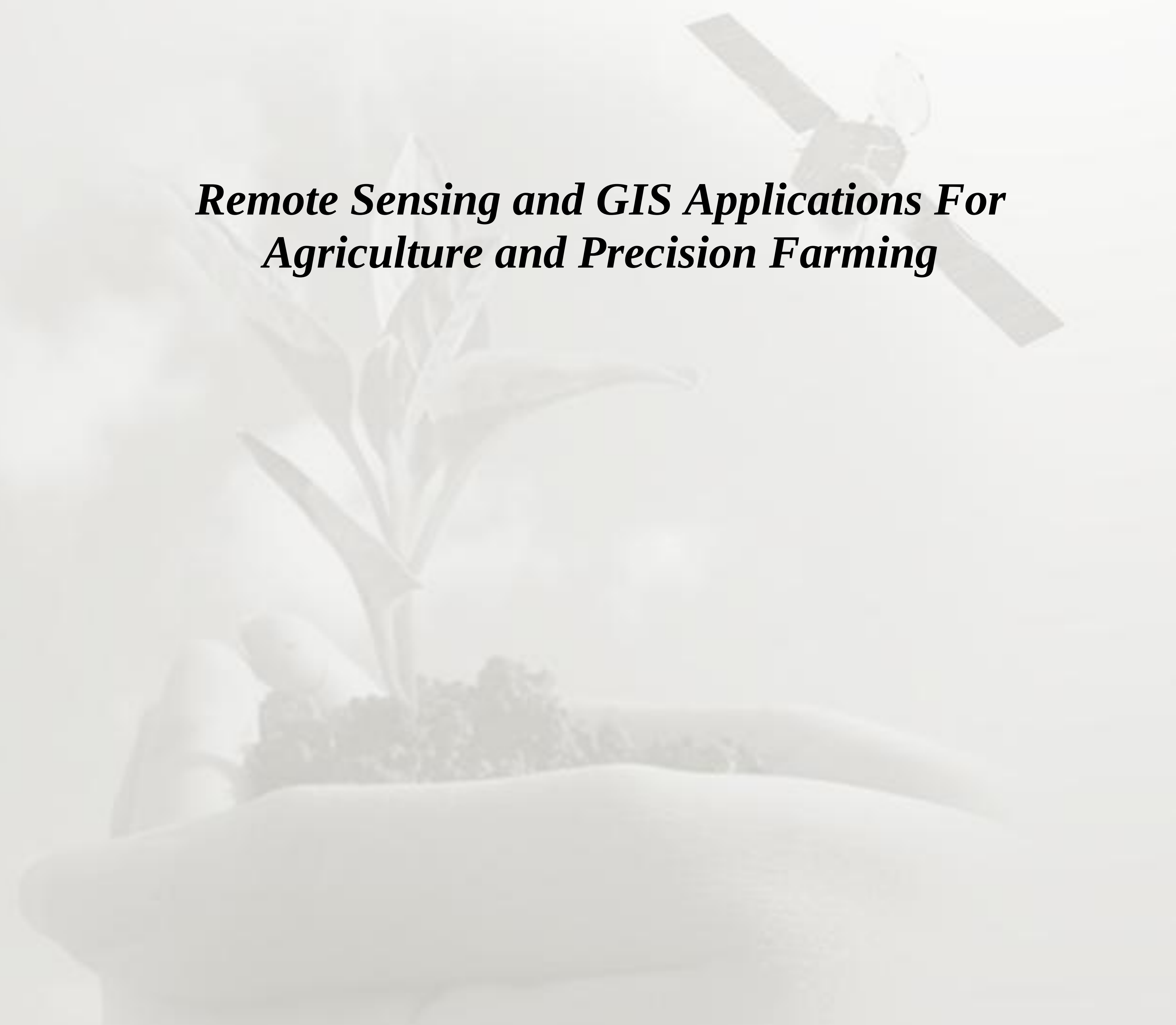
Remote Sensing and GIS Applications For Agriculture and Precision Farming



The Use of Low-cost Webcams for Field Monitoring in Agricultural Farm

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Abstract— **The demand of captured images at agricultural farm is getting more important for recognizing field condition from remote site. However, as high durability is required for field observation instruments, they usually would be costly. In this study, the potential of low-cost USB webcams for field monitoring was investigated. USB webcam was controlled by a tiny Linux box in which moving components were removed to improve endurance under high temperature and humidity condition. The developed system was put in the chassis to prevent the occurrence of dew condensation and the invasion of insects and dust. The quality of the images captured by the system was high enough to evaluate the field condition. It was also supposed to be applied to diagnose the crop growth by non-contact image analysis.**

Keywords-webcam, image capture, field monitoring, Linux box, USB

I. Introduction

The information arising in the agricultural field is very useful to understand what is happening in the filed. It is also important as good record to know the techniques for excellent agriculture practices. Therefore, many systems had been developed to acquire the field condition. Most famous one is a Field Server [1].

A Field Server is one of the smallest monitoring sensor-nodes that are equipped with a Web server to be accessed via the Internet. It has a feature that it provides a high-speed transmission network compared to traditional sensor-nodes. It is because it uses the Internet friendly technique of WiFi [1]. One can measure various physical properties, such as temperature, humidity, soil moisture, and so on, with proper sensors. As Field Server contains a web server inside, users can easily access and obtain their measured data with web-browser through the Internet. It means that no specific programs are necessary to collect the latest observed values from Field Server. However Field Server was used in many research projects, it had not spread so much to farmers. It is supposed that it was mainly from its price. Although Field Server has more functions and advantages than other sensor-node systems, it is too expensive for farmers to find benefits of Field Server.

Another method to evaluate crop condition is image analysis. Sophistication and dissemination of digital still camera have been boosted this field. This method was enables noncontact and nondestructive diagnosis of crop condition which includes water stress, tree vigor, nutrient contents, and so on.

For example, reference [2] tried to estimate water stress degree of tomato trees from the captured images. They spread a blue sheet behind a tomato tree to easily find the moderate threshold value to separate the plant area and background. They found that the value of the plant area was decreased if the tomato was under water stress. Reference [3] applied morphology to analyze plant condition. They used the image of canopy of potted Forsythia and calculated the shape parameter; invariant moments, fractal dimension and skeleton measure. Then they investigated relations between plant condition and these parameters.

Above studies used images captured indoors, because they could avoid the influence of varying lightening condition. Some researchers tried to use the images captured at outdoor field. Reference [4] used the field image to calculate the percentages of weeds, crop and soil present area. The performance of the developed system was shown for a set of image acquired from different field and under different, uncontrolled conditions, such as different light, crop growth stage and size of weeds. Correlation coefficients reached almost 80% to real data.

As seen above, many researchers are working on image analysis in agricultural field; there is a growing need for the system to capture images in the field and to transfer them through the Internet. However many network cameras are available on the market, there are few high-quality models which are also inexpensive.

Authors developed a field image monitoring system based on embedded Linux [5]. As the system was supposed to be installed in the field, it was designed under three requirements; low-cost, robustness to endure in field condition and network gateway function in the field. A wireless broadband router and some USB devices were applied in the system to meet these requirements. In addition, Embedded Linux was installed into the router to control the system. An image was captured by a USB webcam and then transferred to a remote server over a third-generation (3G) network. The developed system almost met pre-defined requirements and it worked fine in the preliminary experiments, but there was still some problems to be operated in agricultural fields; performance of the wireless broadband router which was a little low for capturing images at the maximum resolution of a USB webcam, and the design of chassis which would protect the system under severe environmental conditions.

This article presents implementation of updated field image monitoring system with a low-cost USB webcam and results of field experiments for verifying the durability of the system under severe outdoor condition.

II. Implementation of the Field Image Monitoring System

A. Components of the System

The developed system consisted of only 2 devices; Linux Box and USB webcam.

eBox-4300 [6] which was produced by ICOP Technology Inc. was used as a Linux Box (figure 1). This device was especially designed for limited physical space and temperature concerns [6]. Although this device is smaller than a general personal computer markedly, it can work like a commercial desktop computer. As its CPU is Intel x86 compatible, many famous Linux distributions and even Microsoft Windows can be installed into it. Furthermore, it has many peripherals such as USB ports, serial ports, Ethernet connector and VGA connector. The most specific feature is that it can boot without an internal HDD.

Generically, it has been said that HDD have less thermal endurance. In fact, Reference [7] showed that the internal HDD could not survive for a long time under high temperature condition from the field experiment with a modified inexpensive small computer. Additionally, Reference [5] showed that the field image monitoring system without internal HDD could have operated stably under the high temperature condition. Therefore, replacing all mechanical parts with electric ones (solid state) is an essential requirement for the field monitoring system. As eBox-4300 can boot from a Compact Flash disk instead of an internal HDD, Debian was adopted as an OS and the necessary packages were also installed for controlling the system. OS for the Intel x86 based CPU eased the burden on users in building the system, because there are much more binary packages were available than Embedded Linux distribution.

Qcam Orbit AF [8] (hereafter Qcam) produced by Logicool was used as a USB webcam (figure 1). This model is one of the highest performance USB cameras which are sold in consumer market. It has a true 2-megapixel sensor and supports high resolution up to 1600 x 1200 pixels. As Qcam is a UVC (USB Video Class) compatible device; most Linux distribution supports this model.

eBox-4300
(from reference [6])

Qcam Orbit AF
(from reference [8])

Figure 1. Components of the field image monitoring system

B. Software

This system mainly carried out three operations; capturing a field image, forwarding the image to a remote server, and deletion old image files from CF disk.

Scripts for automated image capturing were called every 10 minutes by a “cron” daemon. At first, it searches a directory named the current date in the working directory. If it were not found, then the system creates the directory to save a captured image file. At the same time, it searches the directories which are older than 30 days from today and removes them to prevent the Compact Flash disk full filled. Then, the system begins to capture a field image by Qcam and save it in the designated directory. At this time, the image capturing software named “fswebcam [9]” is used. Although most image capturing software for Linux supports only Video4Linux 1 (V4L1), fswebcam supports not only V4L1 but also Video4Linux2 (V4L2) which is implemented by a UVC driver. Finally, image files are transferred to a remote server through the Internet. Synchronization between a Linux box and a remote server is done by “rsync [10]” which is an open source utility that provides fast incremental file transfer [10]. Public key authentication is used to transfer images automatically and secure network communication.

III. Field Experiments

A. Site Location

Field experiments were carried out in Kanayama Pilot farm, Mie prefecture, Japan. This area is famous for mandarin orange production. The mean maximum temperature exceeds 30 degrees Celsius in summer; especially Japan is experiencing record high temperatures this year. Humidity also becomes very high in Japan. Furthermore, the field catches the sun because it is located in the southeast-facing slope. In this study, the system was set up near the hut where ADSL line was installed. Although the communication speed was very slow, it was enough to transfer a still image file to the server in Mie University through the Internet every 10 minutes.

The system was exposed to direct sunshine in order to bring environmental condition close to field ones. Power-supply code and LAN cable were extended from the hut. A tree was chosen as an object, in which many kinds of citrus trees were grafted.

B. Preliminary Experiment

Before designing chassis for USB webcam, preliminary experiment was carried out to extract problems. The USB webcam was put into the translucent plastic container temporarily. One side of the container was cut off and replaced by a clear acrylic board for the webcam’s view window. A hole was also opened at the bottom of the container to be connected a flexible tube for wiring the USB cable to a Linux box. The USB webcam was fixed in the container with putty after adjusting the position.

Figure 2 shows inside of the plastic box. Linux box, circuit breaker and additional AC outlet were included in the box. Two flexible tubes were connected to it. One was used to wire the power supply code and Ether cable from the hut. The other was connected to the container which included USB webcam to wire USB code. The role of flexible tube was preventing cables from water, insects and wild animals.

This temporary system was installed in January 27, 2010 and the preliminary experiment ended April 30, 2010.

Figure 2. The plastic box for Linux box

C. Problems Related to the Chassis

Fig. 3 is a side view of the USB container used in the preliminary experiment on April 30. Obviously, about 1 cm of water accumulated inside the container, although most conspicuous clearance was filled up with silicon caulking compound. It was thought that it was caused by dew condensation. As daily range of temperature becomes large around winter in this area, warmed humid air during daytime would be cooled at night and then precipitate as dew. Fortunately most electric parts was located at the top of this webcam, it continued capturing under these severe condition. However, it was found that countermeasures against dew condensation was emergent for the chassis.

Fig. 4 shows the image captured by this monitoring system in the morning of April 30. It was realized that the image had two problems; blurring around the corner and vague white point which was appeared in the center.

The problem of blurring was found in all the images. As this USB webcam had automatic focus adjustment function, it was seemed that it was caused by something focus inhibition. Some dirt on the acrylic board might have caused this problem.

Vague white point was found in many images captured around noon on the sunny day. It was considered that this was reflection. As the container was translucent, most solar ray went into the plastic box. In fact, similar problems had occurred on the images captured by Field Server in Kanayama. The Field Server type IV used a cylindrical acrylic board for the camera window. Reflection occurred from noon to evening. The chassis should be made from light shielded material.

Figure 3. The USB webcam plastic box in preliminary experiment captued on April 30, 2010.

Figure 4. The image captured by this system at 11 AM, April 30, 2010

D. Final Experiment

The chassis of USB webcam was designed based on the results of the preliminary experiments. Fig. 5 shows that the appearance of the chassis of webcam (left) and the detail of the new USB webcam chassis (right). Exterior of the chassis was made from PVC tubes. Two punching metal boards were tied up at the joint of the tubes to fix the webcam and a cup for dry silica gel. Fine mosquito netting screen was tied up at point to prevent invasion of insects. Top side of the chassis was closed by wooden board with glass window for webcam. The webcam’s code to USB connector was passed through the flexible tube in point B. Inside of the chassis was painted black in order to reduce reflection. All apertures except the bottom hole in this chassis were filled up with silicon caulking compound.

This chassis was replaced with the previous plastic container on April 30 and the experiments had been continuing.

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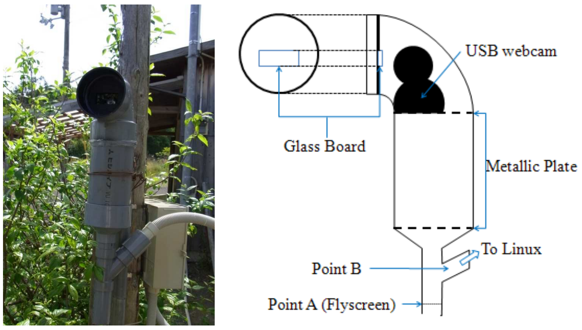

Figure 5. The chassis for USB webcam

IV. Results and Discussion

Fig. 6 is the image captured at same time of the next day of Fig. 4. The problems which were found in the preliminary experiment were almost solved after the chassis was exchanged. Improved system supplied images in high resolution that was thought to be useful for image analysis.

The system halted only once in May 22, 2010. Analyzing logs of the router and the Linux box showed that there was no blackout on that day and electric power was supplied during these periods. After restarting the Linux box on June 6, it started working. This problem was seemed to be occurred by the Linux plastic box because it hadn't been waterproofed completely. After filling up with silicon caulking compound, this system had continued working until now.

Figure 6. The image captured in the final experiment at 11 AM, May 1, 2010

V. Conclusion

Low-cost USB webcam was used for field image monitoring system. Preliminary experiment with the plastic container extracted collected required conditions for the chassis of USB webcam.

The system had been working under Japanese hot and humid summer during the field experiment, except in the case of sudden hang up of the Linux box. This result showed that the developed system had high resistance properties for the severe field condition

Since the image captured by this field image monitoring system was in high resolution, it was thought that the image would be able to be used for image analysis such as measuring the size of fruits if the image was captured at the close-up position.

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